

Turbulence Fluxes

James N. Moum

College of Oceanic & Atmospheric Sciences

Oregon State University

Corvallis, OR 97331-5503

ph: (541) 737-2553 fx: (541) 737-2064 email: moum@oce.orst.edu

<http://www.oce.orst.edu/po/mixing/index.html>

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LONG-TERM GOALS

The long-term goal of this program is to understand the processes by which heat and mass are transported vertically by turbulent processes in the ocean in order to estimate the rates of these transports. Our ongoing studies of both the kinematics and dynamics of turbulence and other small-scale physical phenomena in the ocean emphasize observations, a continual program of sensor and instrumentation development, and interaction with turbulence modelers.

OBJECTIVES

Our objectives are to:

- participate in a collaborative experiment to
 - determine the influence of small topographic features and solitons on mixing of water masses and flow drag over the continental shelf, and
 - determine the generation and dissipation of solitons over the Oregon shelf
- complete investigations of high- k conductivity gradient spectra to resolve the form of the temperature-salinity cross-spectral contribution, using data obtained in the past two years
- make the 1st systematic estimates of the turbulent diffusivity for salt in comparison to simultaneous estimates for heat
- complete analyses of and publish results from pilot studies of hydraulically-controlled flow over Stonewall Bank.

APPROACH

An experiment to occur in June 2000 is now in the final planning stages to further investigate the nature of hydraulic flows we have observed on the continental shelf. This will be done in collaboration with David Farmer (IOS) and Larry Armi (SIO) and will employ Farmer's acoustic imaging techniques to identify the fine scales of the flow and our turbulence profiler *CHAMELEON* to quantify the energy lost to turbulence, the turbulent drag and the mixing of fluid. A schematic of the sampling scheme is shown in Figure 1. A similar collaboration and instrumentation will be used to investigate the evolution of internal solitary waves propagating on to the Oregon shelf in an experiment planned for summer 2001.

Key individuals are Jim Moum and graduate student Jonathan Nash from Oregon State University, David Farmer from the Institute of Ocean Sciences in Sidney, BC and Larry Armi from Scripps.

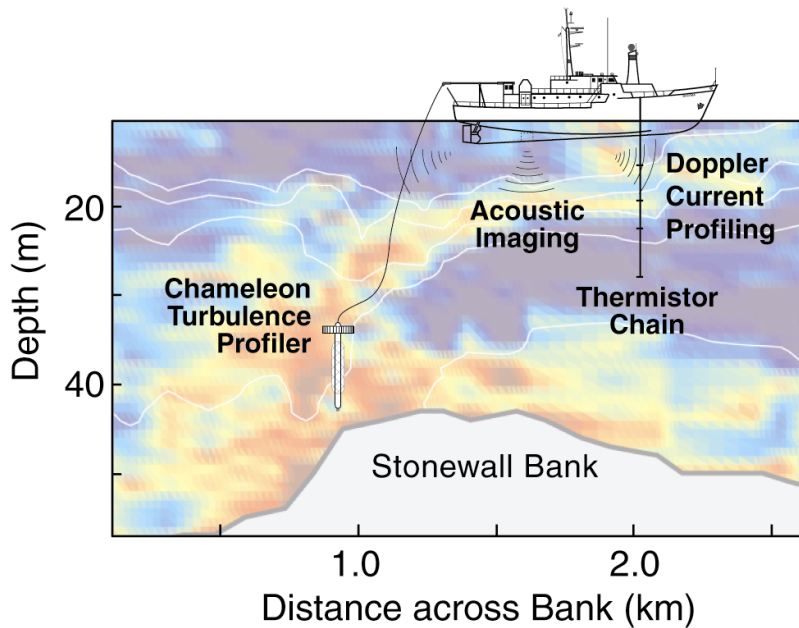


Figure 1 - Deployment of instrumentation to be used over Stonewall Bank. A similar deployment will be used to study solitary waves at the site of the 1995 Coastal Ocean Probe Experiment (COPE). The background image depicts the turbulent dissipation rate, where red is several orders of magnitude greater than blue (Moum and Nash, 1999).

WORK COMPLETED

One paper in which the salient features of hydraulic flow around Stonewall Bank are identified and drag and mixing due to the bank estimated is now in press. Another paper has been submitted in which the evolution of the flow has been examined in detail, the existence of high drag states related to Froude number and newer (1999) results incorporated in the analysis. The determination of salinity variance dissipation rate and estimation of turbulent diffusivity for salinity from high wavenumber conductivity gradient measurements have been demonstrated in a paper published in J.Atmos.Ocean Technol. in 1999. The use of a thermocouple to resolve temperature gradient spectra has been documented in a paper to appear in J.Atmos.Ocean Technol.

RESULTS

The thermocouple is capable of resolving temperature gradients at least ten times thinner than can be resolved by the commonly-used thermistor (Figure 2), and has proven to be sufficiently stable for oceanic use, although noise remains a problem in regions of small temperature gradients.

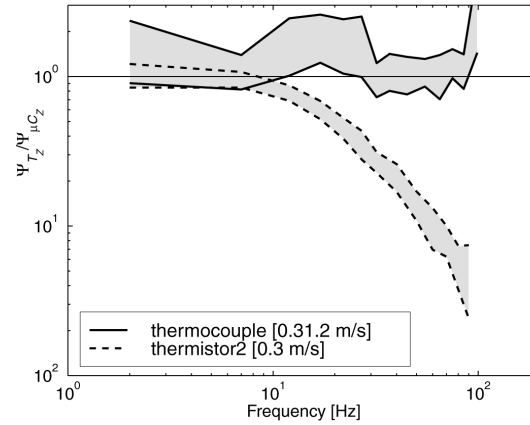


Figure 2 - Ratio of spectral power of thermocouple and thermistor temperature gradient normalized by temperature gradient determined from a fast microconductivity probe. Shaded regions are 95% bootstrap confidence intervals

The intense, topographically-induced mixing over the continental shelf can be considered in terms of an eddy diffusivity. During episodes of hydraulic flow (the frequency of which are unknown to date), mixing is enhanced by $10^2 - 10^3$ times over background values determined from our own and other measurements over the continental shelf and in the open ocean thermocline (Figure 3).

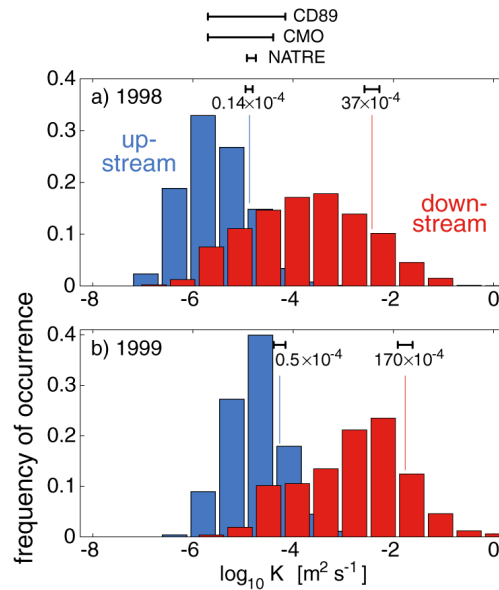


Figure 3 – Distributions of eddy diffusivity, K_p , determined from CHAMELEON measurements of turbulence upstream (blue) and downstream (red) of Stonewall Bank in 1998 (a) and 1999 (b). Mean values and confidence limits are shown and compared to measurements over the continental shelf off Vancouver Island (CD89), over the shelf off the east coast of the US (CMO) and from the ocean thermocline in mid-gyre (NATRE).

IMPACT/APPLICATION

We have identified a previously-unappreciated source of drag and mixing for the circulation of the coastal ocean. The importance of local, intermittent sources of high drag and intense mixing has been considered by us but ultimately must be determined from models of flow over the shelf.

The determination of salinity gradient variance permits a more complete examination of the small-scale entropy generation problem and, for the first time, a comparison of the eddy diffusivities of heat and salt.

PUBLICATIONS

Moum, J.N. and J.D. Nash, 1999: Topographically-induced drag and mixing at a small bank on the continental shelf. in press, *J. Phys. Oceanogr.*

Nash, J.D. and J.N. Moum, 2000: Internal hydraulic flows on the continental shelf: high drag states over a small bank. submitted to *J. Geophys. Res.*

Nash, J.D. and J.N. Moum, 1999: Estimating salinity variance dissipation rate from microstructure conductivity measurements. *J. Atmos. Oceanic Technol.*, 16, 263-274.

Nash, J.D., D.R. Caldwell, M.J. Zelman and J.N. Moum, 1999: A thermocouple probe for high speed temperature measurements in the ocean. in press, *J. Atmos. Oceanic Technol.*

Skyllingstad, E., W.D. Smyth, J.N. Moum and H. Wijesekera, 1999: Turbulent dissipation during a westerly wind burst: a comparison of large eddy simulation results and microstructure measurements. *J. Phys. Oceanogr.*, 29, 1–28.

Smyth, W.D. and J.N. Moum, 2000a: Evolution of turbulence in stably stratified mixing layers. Part 1: Length scales. submitted to *Phys. Fluids A*.

Smyth, W.D. and J.N. Moum, 2000b: Evolution of turbulence in stably stratified mixing layers. Part 2: Anisotropy. submitted to *Phys. Fluids A*.